Public Health Aspects of Antibiotic Resistance Monitoring in the USA

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Abstract

Treatment of food-producing animals with antimicrobial agents that are important in human therapy may present a public health risk by the transfer of resistant zoonotic pathogens or resistant genes from animals to humans via consumption of contaminated food. Resistant bacteria can diminish the effectiveness of antibiotics and demand the use of more expensive or less safe alternatives. In 1996, the U. S. Food and Drug Administration (FDA), the Centers for Disease Control and Prevention (CDC), and the Department of Agriculture (USDA) established the National Antimicrobial Resistance Monitoring Program to prospectively monitor changes in antimicrobial susceptibilities of zoonotic enteric pathogens from human and animal clinical specimens, from healthy farm animals, and from carcasses of food-producing animals at slaughter plants. Data resulting from the monitoring program will be used to redirect antimicrobial drug use, primarily through educational initiatives directed at health practitioners, in order to diminish the development and spread of resistance. Veterinary testing is conducted at USDA's Agricultural Research Service and CDC's Foodborne Disease Laboratory is testing human isolates under contract to FDA. Both the CDC and USDA laboratories are using a semi-automated system (Sensititre™, Accumed, Westlake, Ohio) for testing susceptibilities of the isolates to 17 antimicrobial agents on a minimum inhibitory concentration plate. Comparable methods for isolate handling are used in both laboratories. This paper describes the development, implementation, and objectives of the National Antimicrobial Resistance Monitoring Program, presents initial data generated by the program, and discusses future plans.

Introduction

The potential public health hazard of veterinary use of antimicrobial agents has been widely debated. In the United States, the discussion was reopened prior to approval of the first fluoroquinolone antibiotic for use in animals intended for food in the United States. In 1995, the U.S. Food and Drug Administration (FDA) approved sarafloxacin for control of illness caused by Escherichia coli in poultry. In 1996, enrofloxacin was also approved for use in poultry. The approval of a fluoroquinolone for use in animals intended as food raised serious public health concerns due to the potential risk of transfer of resistant bacteria and resistance genes from animals to humans. Cross resistance occurs throughout this entire class of drugs; thus, resistance to one fluoroquinolone compromises the effectiveness of all fluoroquinolone drugs whether used in animals or humans. Antibiotic use selects for populations of resistant bacteria in target pathogens and normal bacterial flora, including food borne pathogens such as Salmonella, Campylobacter, and E. coli O157. If resistant food borne pathogens are present in food animal species, these bacteria may contaminate food products at the time of slaughter and be transmitted to humans through the food chain (6). Extensive antibiotic use increases the spread of antibiotic-resistant bacteria by creating selective pressure favoring resistant bacteria (11). The public health impact of resistance on the population includes increased morbidity and mortality from treatment failures and increased health care costs as newer, more expensive antibiotics are needed to treat infections (1). Development of antimicrobial resistance has emerged as a global problem. Expert scientific groups such as the Institute of Medicine, the American Society for Microbiology and the World Health Organization have expressed apprehension about

the national and global increase in antibiotic resistance and the complex issues surrounding this increase in both the community and institutional settings (1,7). Recently, resistance has been observed in bacteria known to cause plague and in Staphylococcus aureus, a common pathogen of wound and blood infections. Additionally, multiple resistance has emerged among many bacterial strains including Salmonella species. A penta-resistant strain of Salmonella Typhimurium DT104 in which the resistance genes have been chromosomally integrated is proving to be particularly problematic, resulting in increased morbidity and mortality in both animals and humans (2,9,13,14,15). The main reservoir appears to be cattle although the organism has been recovered from a variety of animal species (9,15).

ANTIBIOTIC RESISTANCE MONITORING -- Methods

Because of the public health concerns associated with the approval of fluoroquinolones for use in food-producing animals in the United States, an antimicrobial resistance monitoring program was developed as a post-marketing activity to help ensure the continued safety and effectiveness of the fluoroquinolones. In 1996, the FDA, the Centers for Disease Control and Prevention (CDC) and the U.S. Department of Agriculture (USDA) established the National Antimicrobial Resistance Monitoring Program to prospectively monitor changes in antimicrobial susceptibilities of zoonotic enteric pathogens from human and animal clinical specimens, from healthy farm animals, and from carcasses of food-producing animals at slaughter plants (4,10).

Veterinary testing is conducted at USDA's Agricultural Research Service. Non-typhoid Salmonella is the sentinel organism selected because it is an important food borne pathogen, reportable to the CDC, and isolates from both human and animal sources are available. CDC's Foodborne Disease Laboratory in the National Center for Infectious Diseases is testing human isolates, both non-typhoid Salmonella and E. coli O157, submitted by 14 State Public Health Laboratories (CA, CO, CT, FL, GA, KS, Los Angeles County, MA, MN, NJ, New York City, OR, WA, and WV). The participating public health laboratories select every tenth Salmonella and every fifth E. coli O157 isolate received at their laboratory and forward the isolates to CDC for susceptibility testing. The populations served by the participating state and county public health laboratories represent a total human population of approximately 75 million persons. Both the CDC and USDA laboratories are using a semi-automated system (Sensititre™, Accumed, Westlake, Ohio) for the testing of isolates; comparable methods for isolate handling are used in both laboratories.

The goals and objectives of the National Antimicrobial Resistance Monitoring Program are to provide descriptive data on the extent and temporal trends of antimicrobial susceptibility in Salmonella and other enteric organisms from the human and animal populations; facilitate the identification of resistance in humans and animals as it arises; provide timely information to veterinarians and physicians; prolong the life span of approved drugs by promoting the prudent use of antibiotics; identify areas for more detailed investigation; and guide research in the area of antibiotic resistance. Information resulting from the monitoring program and follow-up outbreak investigations will be distributed to veterinarians, physicians, and food animal producer groups in a timely manner. Use of the information will be targeted to redirecting drug use so as to diminish the development and spread of resistance over the short term with directives involving long-term use developed in collaboration with the appropriate professional practitioner groups. Outbreak investigations and field studies will be initiated as a result of major shifts or changes in resistance patterns in either animal or human isolates.Because of the public health

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ANTIBIOTIC RESISTANCE MONITORING -- Results

Veterinary baseline testing was completed at USDA in 1996; changes in susceptibility profiles and emergence of resistance are compared to the patterns seen in these baseline isolates. The veterinary isolates selected for baseline testing (n=1,041) consisted of clinical and non-clinical Salmonella isolates collected in 1994 and 1995. Breakpoint concentrations were determined for 16 antimicrobics (Table 1).

Table 1.
ANTIMICROBIAL AGENTS USED IN THE NATIONAL MONITORING SYSTEM and CONCENTRATIONS in 1g/ml

ANIMAL ISOLATES BREAKPOINT PLATE (Baseline & 1996*)	HUMAN ISOLATESMIC PLATE(1996)	ANIMAL AND HUMAN ISOLATES (1997 and beyond)
Amikacin (16 - 32)		Amikacin (4 to 32)
Amoxicillin/Clavulanic Acid(8/4 - 16/8)	Amoxicillin/Clavulanic Acid(2/1 to 16/8)	Amoxicillin/Clavulanic Acid(0.5/0.25 to 32/16)
Ampicillin (16 - 32)	Ampicillin (1 to 64)	Ampicillin (2 to 64)
Apramycin (8)	Apramycin (2 to 16)	Apramycin (2 to 16)
Ceftiofur (2 - 4)	Ceftiofur (0.25 to 32)	Ceftiofur (0.5 to 16)
Cepotaxime (8 - 32)	Ceftriaxone (0.25 to 16)	Ceftriaxone (0.25 to 16)
Cephalothin (8 - 16)	Cephalothin (0.25 to 32)	Cephalothin (1 to 32)
Ciprofloxacin (1 - 2)	Chloramphenicol (4 to 32)	Chloramphenicol (4 to 32)
Gentamicin (4 - 8)	Ciprofloxacin (0.03 to 4)	Ciprofloxacin (0.015 to 2)
Neomycin (8)	Gentamicin (0.25 to 16)	Gentamicin (0.25 to 16)
Piperacillin (16 - 64)	Kanamycin (8 to 64)	Kanamycin (16 to 64)
Sulfamethoxazole (256)	Nalidixic Acid (0.5 to 64)	Nalidixic Acid (4 to 64)
Tetracycline (4 - 8)	Streptomycin (32 to 256)	Streptomycin (32 to 256)
Ticarcillin (16 - 64)	Sulfamethoxazole (64 to 512)	Sulfamethoxazole (128 to 512)
Ticarcillin/Clavulanic Acid (16/2 - 64/2)	Tetracycline (4 to 32)	Tetracycline (4 to 64)
Trimethoprim/Sulfamethox (2/38)		Ticarcillin (2 to 128)
	Trimethoprim/Sulfamethox (.12/2.4 to 8/152)	Trimethoprim / Sulfamethox (0.12/2.4 to 4/76)

* 1996 animal isolate testing included determination of minimum inhibitory concentrations to nalidixic acid (0.5 to 32 1g/ml) and ciprofloxacin (0.03 to 4 1g/ml)

No fluoroquinolone resistance was detected in the baseline isolates, but there was clinically significant resistance to other antimicrobial agents. The most common resistance among the animal Salmonella isolates was to tetracycline (34% resistant). Other common resistances were to sulfamethoxazole (28%), ticarcillin and ampicillin (13% each), neomycin (8%) and piperacillin (7%). Percent resistance for both clinical and nonclinical isolates for ampicillin, sulfamethoxazole, tetracycline, and ticarcillin by species for the baseline isolates is shown in Table 2.

Table 2.
PERCENT RESISTANCE BY SPECIES OF THE VETERINARY BASELINE *SALMONELLA* ISOLATES

ANIMALSPECIES	AMPICILLIN	SULFA	TETRA- CYCLINE	TICARCILLIN
CATTLE n=479	14%	16%	24%	14%

SWINE n=311	10%	45%	50%	10%
CHICKEN n=116	14%	14%	34%	16%
TURKEY n=57	7%	68%	47%	9%

The veterinary Salmonella isolates collected during 1996 (n=1,922) were also derived from both clinical and non-clinical samples. Breakpoint concentrations were determined for 16 antimicrobics plus minimum inhibitory concentrations (MICs) were determined for naladixic acid and ciprofloxacin (Table 1). The non-clinical isolates were collected from healthy animals on farm (n=899) and from healthy animals at slaughter (n=150). Clinical isolates (n=873) were randomly selected from National Veterinary Services Laboratory (USDA) submissions and included a small number of samples from companion and exotic animals (n=124).
The most common resistance among the Salmonella isolates collected during 1996 (clinical and non-clinical) was to tetracycline (47% resistant). Other common resistances were to sulfamethoxazole (35%), ticarcillin and ampicillin (19% each), neomycin (14%), and piperacillin (13%). Percent total resistance of the isolates collected in 1996 by species for swine, cattle, chickens, and turkeys is shown in Table 3.

Table 3.
PERCENT RESISTANCE BY SPECIES OF THE *SALMONELLA* VETERINARY ISOLATES COLLECTED IN 1996

ANTIBIOTIC	SWINE	CATTLE	CHICKEN	TURKEY
AMIKACIN	0	0	0	0
AMOX/CLAV	1	2	1	16
AMPICILLIN	20	21	6	34
APRAMYCIN	5	<1	0	2
CEFOTAXIME	0	2	0	2
CEFTIOFUR	0	2	1	8
CEPHALOTHIN	1	2	2	22
CIPROFLOXACIN	0	0	0	0
GENTAMICIN	3	3	29	64
NEOMYCIN	15	35	5	16
PIPERACILLIN	13	12	3	26
SULFAMETHOX	45	22	31	68
TETRACYCLINE	68	23	53	34
TICARCILLIN	20	43	4	34
TICAR/CLAV	9	9	1	20

TRIMETH/SULFA	4	3	1	4

A total of 3,075 Salmonella isolates have been collected during 1997 but not yet analyzed. These isolates are from healthy animals on-farm (n=1,500), healthy animals at slaughter (n=700) and the National Veterinary Services Laboratory (n=875, all clinical) which included 75 isolates collected from companion and exotic animals.

Baseline human data has been collected by CDC in community surveys of clinical isolates, from 1980-1995 at 5-year intervals for Salmonella. Overall resistance as well as multiple resistance has increased over time. About 30% of the Salmonella isolates were resistant and approximately 20% were multi-resistant. This varied by serotype with S. Typhimurium showing about 50% resistance and S. Enteritidis remaining close to pan sensitive. The drugs most commonly inducing resistance included tetracycline, sulfamethoxazole, streptomycin and ampicillin.

A total of 1,272 human Salmonella and 187 human E. coli O157 clinical isolates were collected by the participating public health laboratories in 1996 and forwarded to CDC. The human isolates were tested at CDC using the Sensititre™ system which determined the MICs for 15 antimicrobial agents (Table 1). Thirty-six percent of Salmonella isolates were resistant to at least one antimicrobial agent, and 30% were multiply resistant. The most common resistance among Salmonella was to tetracycline (24%); other common resistances were to sulfamethoxazole (22%), streptomycin (21%) and ampicillin (21%) (Table 4).

Table 4.
ANTIBIOTIC SUSCEPTIBILITY RESULTS (PERCENT) OF *SALMONELLA* HUMAN ISOLATES FOR 1996

ANTIBIOTIC	SUSCEPTIBLE	INTERMEDIATE	RESISTANT
AMOX/CLAV	86.5	12.2	1.3
AMPICILLIN	78.9	0.2	20.9
APRAMYCIN	99.1	0.7	0.2
CEFTIOFUR	96.0	0.2	3.8
CEFTRIAXONE	99.9	0.1	0.0
CEPHALOTHIN	93.5	3.3	3.2
CHLORAMPHEN	89.1	0.6	10.4
CIPROFLOXACIN	100.0	0.0	0.0
GENTAMICIN	94.7	0.2	5.0

KANAMYCIN	94.8	0.4	4.8
NALIDIXIC ACID	99.6	0.0	0.4
STREPTOMYCIN	79.4	0.0	20.6
SULFAMETHOX	77.9	0.0	22.1
TETRACYCLINE	75.6	0.6	23.8
TRIMETH/SULFA	96.0	0.0	4.0

Twenty percent of human E. coli O157 isolates were resistant to at least one antimicrobial agent and seven percent were resistant to two or more drugs. The most common resistance among E. coli O157 was to sulfamethoxazole (13%); other common resistances were to tetracycline (5%), ceftiofur (5%), and cephalothin (3%) (Table 5).

Table 5.
ANTIBIOTIC SUSCEPTIBILITY RESULTS (PERCENT) OF *ESCHERICHIA* COLI O157 HUMAN ISOLATES FOR 1996

ANTIBIOTIC	SUSCEPTIBLE	INTERMEDIATE	RESISTANT
AMOX/CLAV	99.5	0.5	0.0
AMPICILLIN	98.4	0.0	1.6
APRAMYCIN	99.5	0.5	0.0
CEFTIOFUR	94.7	0.0	5.3
CEFTRIAXONE	100.0	0.0	0.0
CEPHALOTHIN	69.5	27.8	2.7
CHLORAMPHEN	99.5	0.0	0.5
CIPROFLOXACIN	100.0	0.0	0.0
GENTAMICIN	100.0	0.0	0.0
KANAMYCIN	100.0	0.0	0.0
NALIDIXIC ACID	100.0	0.0	0.0
STREPTOMYCIN	98.4	0.0	1.6
SULFAMETHOX	87.2	0.0	12.8
TETRACYCLINE	94.1	1.1	4.8
TRIMETH/SULFA	100.0	0.0	0.0

No Salmonella or E. coli O157 isolates tested were resistant to ciprofloxacin or ceftriaxone. Five isolates of Salmonella were resistant to nalidixic acid. Of all human Salmonella isolates received at CDC, 345 (27%) were serotype Enteritidis and 292 (23%) were serotype Typhimurium.

Both laboratories in 1997 began using a preconfigured panel designed for the Sensititre™ system to determine the MICs for the same 17 antimicrobial agents: amikacin, amoxicillin/clavulanic acid, ampicillin, apramycin, ceftiofur, ceftriaxone, cephalothin, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfamethoxazole, tetracycline, ticarcillin, and trimethoprim/sulfamethoxazole (Table 1). In 1997, monitoring of human isolates expanded to include Campylobacter species; monitoring of veterinary E. coli and Campylobacter isolates will begin in 1998.

Discussion

The National Antimicrobial Resistance Monitoring Program is only a sentinel: it can not tell us how or why, from what source, or by what mechanism resistance has emerged. Additional, more focused analytical studies will be needed to fully determine the association between antimicrobial resistance in the human and animal populations. To begin to address these limitations, several additional studies are planned.

Although fluoroquinolone resistance has not been shown to be transferrable in nature to date, the same was true of vancomycin resistance several years ago (3,5,8). Therefore, we will be screening fluoroquinolone-resistant isolates as they are received to determine if transferrable fluoroquinolone resistance has developed. If transferrable resistance is identified, it would indicate a need for expanded monitoring in appropriate human pathogens rather than just zoonotic enteric organisms, and would escalate the potential public health hazard. If similar strains of Salmonella appear in both the veterinary and the human populations studied in the monitoring system (same serotype and same antimicrobial resistance pattern), we will attempt molecular comparison of strain characteristics in the same laboratory to define their degree of similarity.

Outbreak investigations and field studies will be initiated as a result of major shifts or changes in resistance patterns in either animal or human isolates. These efforts will include a trace back system to determine the source of the infection and the circumstances that led to the resistance. Other data collection efforts are planned including prescribing surveys of physicians and veterinarians to assess the impact of antimicrobial drug use on resistance patterns and prevalence to guide regulatory policy as well as education campaigns on the prudent use of antibiotics.
Beginning in 1998, we plan to increase collection of Salmonella isolates from healthy animals at slaughter plants. The slaughter plant Salmonella isolates will be obtained from the USDA which has mandated slaughter plants to sample for Salmonella to ensure compliance with pathogen reduction performance standards as part of a plant's Hazard Analysis and Critical Control Point program (HACCP) (12). This program must be in effect on January 25, 1998 for slaughter plants with 500 or more employees. These large slaughter plants in total account for 75% of the annual meat

and poultry production in the U.S. Also in 1998, FDA plans to establish veterinary sentinel sites at veterinary diagnostic laboratories in the states of Washington, New York, and Minnesota.

The plans for expansion will greatly increase the number of isolates submitted to the National Antimicrobial Resistance Monitoring Program obtained from both healthy animals at slaughter and from veterinary diagnostic laboratories which will submit clinical isolates. Also, the number of state public health laboratories submitting human isolates was increased by two in late 1997 (New York and Maryland) and an additional site will be added in 1998. These ambitious expansion plans have arisen from a U.S. National Food Safety Initiative which will be implemented in 1998.

There are an estimated 6.5 to 33 million food borne illnesses and up to 9,000 deaths every year in the United States. Hospital stays alone due to these illnesses cost more than $3 billion annually. The goal of the National Food Safety Initiative is to reduce, to the greatest extent possible, the incidence of food borne illness. Six specific areas are targeted under the Food Safety Initiative: Inspections, Risk Assessment, Education, Outbreak Coordination, Bioscience Research, and Surveillance.

The Inspections component of the Food Safety Initiative is designed to produce a more efficient and effective monitoring of the safety of the food supply. FDA and USDA plan to continue development of HACCP based food safety systems. FDA plans to implement HACCP in the seafood industry and expand the use of HACCP to appropriate commodities such as produce. Other plans include an expansion of Federal-State inspection partnerships to ensure consistency in inspection techniques across Federal, State, and local levels.

The goal of the Risk Assessment project is to improve the analysis of risks associated with food borne hazards in order to facilitate the development and evaluation of surveillance plans, preventive strategies, and research programs to enhance food safety. Plans are underway to establish a consortium to provide leadership in risk assessment and risk management and to provide guidance for future risk assessment research including the development of better modeling techniques and the development of dose-response models for use in microbial risk assessments.

Under the Education initiative, projects are planned to develop education programs designed to change unsafe food handling behavior in the home and in retail, food service, and institutional operations. Other projects will determine more effective methods for providing food service education materials and services. A national food safety education program for food service workers and for all segments of the retail food industry will be developed and implemented in 1998. Finally, a major food safety consumer education initiative is planned in conjunction with the food industry. Also during 1998, CDC is implementing an extensive education campaign on proper antimicrobial drug use directed at physicians. Using the experience of these 1998 education activities, in 1999 an education program will be developed for food animal producers and veterinarians on the prudent use of antimicrobial drugs in food animals.

The main focus of the Outbreak Coordination initiative is improved coordination of response to outbreaks of food borne illness at all levels of government to ensure that responses are rapid and effective and avoid unnecessary duplication of effort. Specific plans include the creation of an emergency response system to manage food borne disease outbreaks, formation of partnerships with State and local governments

to achieve better Federal-State coordination on outbreaks, and providing States with additional epidemiological resources to better respond to food borne illness outbreaks.

Several goals are incorporated into the Bioscience Research component of the Food Safety Initiative. New, improved screening and analytical methods will be developed to more rapidly and accurately identify and characterize food borne hazards. Research can also help to evaluate the effectiveness of surveillance initiatives as well as control and prevention strategies and verify the effectiveness of preventive techniques such as HACCP programs. FDA Center for Veterinary Medicine projects under the research component of the Food Safety Initiative include development of improved detection methods for food borne pathogens in animal feed, identification and characterization of factors that lead to the development of antimicrobial drug resistance in food borne pathogens in farm animals and aquaculture, and expanded investigation of techniques such as competitive exclusion products to limit or avoid resistance. FDA is encouraging the development of alternative strategies to antibiotic usage such as improved management techniques and novel drug treatments to reduce both the overall prevalence of pathogens carried by animals and specifically target resistant pathogens.

The goal of the Surveillance Initiative is the rapid detection of food borne illness outbreaks and dissemination of information to facilitate immediate control mechanisms, and ultimately to reverse the trend of animal pathogen resistance development and reduce the transfer of resistant animal pathogens to humans. The National Antimicrobial Resistance Monitoring Program is FDA's focal point under the Surveillance Initiative. Through this program, FDA will develop systematic and timely information upon which to base public health decisions relating to the control of resistant food borne pathogens and to assist practitioners in the appropriate use of antimicrobial agents. Ongoing national surveillance of antimicrobial resistance will be expanded to new sites and new sources of isolates and physician and veterinary drug prescribing surveys will be conducted to assess the impact of antimicrobial use on resistance patterns and prevalence.

The identification of emerging resistance and the capability to investigate resistance patterns and trends identified through the National Antimicrobial Resistance Monitoring Program are essential elements to facilitate timely and appropriate public health response activities. Further development of a multi-agency coordinated response will promote punctual communication, informed decision making, and proactivity in assisting veterinarians and physicians in the prudent use of antimicrobial agents. The ultimate outcome will be to prolong the efficacy of existing and new antimicrobial agents which are desperately needed to control both human and animal disease and to minimize the spread of resistant zoonotic pathogens to humans.

References

1. American Society for Microbiology Public and Scientific Affairs Board. Report of the ASM Task Force on Antibiotic Resistance, Washington, D.C., March 16, 1995.
2. Anonymous. Salmonella in animal and poultry production 1992. Ministry of Agriculture, Fisheries, and Food. Welsh Office, Agricultural Department, Scottish Office, Agriculture and Fisheries Department, 1993.

3. Bates, J., Jordens, J. Z., Griffiths, D. T. Farm animals as a putative reservoir for vancomycin-resistance enterococcal infection in man. J. Antimicrob. Chemother. 1994, 34:507-516.
4. Centers for Disease Control and Prevention. Notice to Readers: Establishment of a national surveillance program for antimicrobial resistance in Salmonella. Morbidity and Mortality Weekly Report 1996, 45:110-111.
5. Courvallin, P. Minireview: Plasmid-mediated 4-quinolone resistance: a real or apparent absence? Antimicrob. Agents and Chemother. 1990, 34:681-684.
6. Holmberg, S.D., Osterholm, M.T., Senger, K.A., Cohen, M.L. Drug-resistant Salmonella from animals fed antimicrobial agents. N. Engl. J. Med. 1984, 311:617-622.
7. Institute of Medicine Committee on Emerging Microbial Threats to Health, Lederberg, J., Shope, R. E., and Oaks, S. C. (Eds.). Emerging Infections: Microbial Threats to Health in the United States, National Academy Press, Washington, D.C., 159-160, 1992.
8. Noble, W. C., Virani, Z., Cree, R. G. Co-transfer of vancomycin and other resistance genes from Enterococcus faecalis NCTC 12201 to Staphylococcus aureus. FEMS Microbiol. Lett. 1992, 72:195-198.
9. Threlfall, E.J., Frost, J.A., Ward, L.R., and Rowe, B. Epidemic in cattle and humans of Salmonella typhimurium DT104 with chromosomally integrated multiple drug resistance. Vet. Rec. 1994, 134:577.
10. Tollefson, L. FDA reveals plans for antimicrobial susceptibility monitoring. J. Amer. Vet. Med. Assoc. 1996, 208:459-460.
11. U.S. Congress, Office of Technology Assessment. Impacts of Antibiotic-Resistant Bacteria, OTA-H-629, Washington, D.C., U.S. Government Printing Office, September, 1995.
12. U.S. Department of Agriculture. Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) Systems; Final Rule. Federal Register 61(144):38806-38989, July 25, 1996.
13. Wall, P.G., Morgan, D., Lamden, K., Ryan, M., Griffin, M. Threlfall, E.J., Ward, L.R., and Rowe, B. A case control study of infection with an epidemic strain of multi-resistant Salmonella typhimurium DT104 in England and Wales. Commun. Dis. Rep. 1994, 4:R130-R135.
14. Wall, P.G., Morgan, D., Lamden, K., Griffin, M., Threlfall, E.J., Ward, L.R., and Rowe, B. Transmission of multi-resistant strains of Salmonella typhimurium from cattle to man. Vet. Rec. 1995, 136:591-592.
15. Wall, P.G., Threlfall, E.J., Ward, L.R., and Rowe, B. Multiresistant Salmonella typhimurium in cats: a public health risk. Lancet 1996, 348:471.

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